

# **DESIGN PROCESS of AIRLOOP-PEDAL:**

## **EXPERIMENTING WITH STANDARD GUITAR PEDALS**

**MASTER'S THESIS  
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## Abstract

My master's thesis, consisting of both a written documentation and an experimental undertaking, is a report of the design process of AirLoop-pedal as well as a brief overview of today's creative solutions in music. Within the scope of my thesis I investigate new creative strategies for guitar signal manipulation and standard guitar pedal controlling.

AirLoop-pedal is a non-contact signal processing device for guitar that is designed to control standard guitar pedal loops through motion detection. This project is an experimental design process supported by the examples of experimental music and interface design introduced in subsequent chapters. The main outcome of the project is a functional prototype of AirLoop-pedal that corresponds with the requirements laid out during the design process.

This work is comprised of two overarching ideas, both of which provide complementary supports to the understanding of this process. These concepts were an integral part of my thinking during the design process of AirLoop-pedal. Firstly: new technology creates new aesthetics of music, and secondly: coincidences have the ability to feed creativity.

During this work I will examine creative strategies for experimental music, focusing on guitar signal processing, coincidental discoveries, experimenting with coincidences, and motion mapping and tracking with musical instruments. In the design of AirLoop-pedal I aim to utilize these main creative concepts, realizations and information gained throughout the duration of the design and building process, as well as my own experience as a musician.

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**Keywords** guitar, guitar pedal, creative music, experimental music, signal processing

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*Cheers!*



# 1 INTRODUCTION

Due to the rapid development of new technology, digital musical instruments are disclosing an ever-growing amount of their sizable potential. Musicians and sound artists are constantly searching for fresh and unique methods of expressing themselves. As a sound designer and musician myself, the new technological potential of music software programs and physical devices I use on a daily basis have inspired me to explore and develop more new creative methods for bending, shaping, and sculpting the music and sounds I compose and design. My Master's thesis, consisting of both a written documentation and an experimental undertaking, is a report of the design process of AirLoop-pedal as well as a brief overview of today's creative solutions in music. Within the scope of my thesis I investigate new creative methods for guitar signal manipulation and guitar pedal controlling.

This work is comprised of two overarching ideas, both of which provide complementary support to the understanding of this process. These dual concepts were an integral part of my thinking during the design process of AirLoop-pedal.

Firstly: **new technology creates new aesthetics of music**. Thom Holmes, the author of *Electronic and Experimental Music: Technology, Music, and Culture*, explained that new experimentation is an inevitable consequence of newly developed technology. Eventually this leads to new guitar tones, new musical styles, and new music production techniques (2008, p. 351).

Secondly: **coincidences have the ability to feed creativity**. The majority of the third chapter is dedicated to importance of spontaneity and coincidental events that take place within the creative process. Within this chapter I discuss the importance of the John Cage's experimentations with coincidence, aleatoric music, and other indeterminate

productive methods, as well as detailing the accidental discovery of the guitar distortion that revolutionized the music industry of the 1960s (Manning, 2004, p. 75; Cage, 1961).

In the design of AirLoop-pedal I aim to utilize these main creative concepts, realizations, and information gained throughout the duration of the design and building process, as well as borrowing from my own experience as a professional guitarist. This project is an experimental design process supported by the examples of experimental music and interface design introduced in subsequent chapters. My final goal is to develop a functional prototype of AirLoop-pedal, and explore new creative methods for controlling standard guitar pedals with it.

**MAIN TERMS:**

***Traditional guitar pedal*** [or stompbox, effect pedal]:

*Analog or digital guitar effect unit designed to sit on the floor with a standard guitar mono input and output sockets (6,3mm) (In stereo versions: 2 in / 2 out).*

***Guitar pedal chain*** [or pedal chain, effect pedal chain]:

*Two or more Traditional guitar pedals connected together in series, one after another.*



*[Picture 01]: Riverdog Samson, BP-Studio Sessions, 2013*

## 1.1 Motivation & personal background

In my profession as a sound designer and composer for movies, games, advertisements, and other fields of media, I work and experiment with several different digital processors and sound design software programs on a daily basis. Often these work productions are executed ‘inside the box’, meaning that the project’s necessary recording, editing and processing is done inside the actual recording application. Additionally, the rooms, echo chambers, and instruments are all virtual. With an almost unlimited amount of central processing unit power available and a plethora of different virtual instruments and plugins, these ‘inside the box’ projects can be extremely cost-effective and quick,

allowing the flexibility and efficiency to explore almost every spontaneous idea.

However, as a guitarist and like the vast majority of my colleagues, I tend to resort to more standardized systems of analog signal processing, sound manipulation, and recording techniques, such as blending a guitar signal between two independent amplifiers with an analog cross-fade pedal.

These experiences have led me to contemplate the following question: is there a way to fuse new technological design ideas with traditional guitar pedals?

To find answers to this question, I decided to explore this idea more by choosing a project based on guitar pedal design. I aim to design and build a prototype of the motion control-based AirLoop-pedal which satisfies the following five goals: the device a) is capable of controlling traditional guitar pedals, b) provides a balance between ease and challenge in regards to control, c) creates interesting and coincidental situations during a performance, d) works as a independent standalone pedal, and e) does not convert the signal to digital at any point of the signal chain.

I have always been fascinated with music and sounds, and have felt that these types of projects of learning through exploration and experimentation have been of the utmost significance during my career as a sound designer, musician, and music producer.

## 1.2 Literature review

The recent literature about creative sound design and guitar signal processing is versatile. Sound designers, musicians, and sound artists are always searching for unique techniques in order to create new and experimental works (Schader, 1982), and there are various theories and interpretations of sound and creative sound processing. This literature review will examine the main issues surrounding my AirLoop-pedal and guitar sound manipulation thesis. In this chapter I investigate literature around creative strategies for guitar signal manipulation, focusing on guitar signal processing, coincidental discoveries, experimenting with coincidences, motion mapping, and tracking with musical instruments. By exploring these areas of literature, this review aims to open new solutions for both creative guitar signal manipulation and experimental music methods.

### GUITAR SIGNAL PROCESSING

In today's audio signal processing (ASP), sound design and audio manipulation possibilities are practically unlimited. Within the scope of this thesis, the term 'audio signal processing' refers to various techniques for changing or manipulating the audio signal. Digital guitar signal processing (with conversions between analog and digital) enables easy interaction with an analog guitar signal, and it also provides relatively easy solutions for my design issues with AirLoop-pedal. The author of *Modern Jazz Guitar Styles* (2004), Andre Bush explains that in the middle 1980s "digital technology was integrated into standard guitar signal processing and guitar synthesis." Signal processing had found a new, revolutionary stage, and around that time many guitarists and authors of the related publications predicted the commercial evanescence of analog guitar signal processing. However, traditional analog guitar pedals never vanished; they have gained even more popularity during last ten years, and often the analogy of the pedal chain is not

a factor of compromise for guitarists. From these points emerge the interesting question of how to find and implement new control solutions to preexisting analog guitar pedal chains without converting the signal to digital.

## **COINCIDENTAL DISCOVERIES**

Sound artist Pierre Schaeffer demonstrated that, almost without exception, newly developed sound technology can open never-before-experienced creative methods for sound artists, eventually leading to new art forms; this has been the fundamental driving force of electroacoustic music and sound art during its rapid and brief development (Schader, 1982). Film director and visual artist David Lynch emphasizes the importance of chance and coincidence in sound design and creativity—when describing the creative processes behind audio technology, Lynch does not underestimate the significance of chance and mistakes:

*Sometimes when you're in doubt or you don't have an idea, creating accidents can break through to some places where you want to be . . . mistakes are an absolutely necessary part of every creative process; that's the only way you figure out what will work and what won't (Sider, Freeman and Sider, 2003).*

## **EXPERIMENTING WITH COINCIDENCE**

Many sound artists have deliberately used coincidence for feeding creativity (Manning, 2004). John Cage, who pioneered the concept of aleatoric music, drew his inspiration from the chaos and coincidence of the natural world, the random reactions of an audience, or chance operations he would employ within his creative processes (Manning, 2004, p. 75; Cage, 1961). Cage's greatest aspiration was to fully exploit the uniqueness of every sonic situation. Many other pioneers of experimental music, such as Pierre Schaeffer, Luigi Russolo, Hugh LeCaine, Vladimir Ussachevsky, Steve Reich, and Otto Luening also used coincidence both compositionally and technically in their creative

works (Schader, 1982). Likewise, the great pioneers of rock, pop, and jazz, such as David Gilmour (Pink Floyd), Miles Davis, Ike Turner, and the Beatles, revolutionized the music industry with new experimental techniques, innovations and coincidental discoveries (Mason, Nick 2004; Leone, Dominique 2006; Winkler, Todd 1998, p. 26).

## **TRACKING AND MAPPING**

The new methods of digital controllers let sound designers (and even the average consumer) control the audio signal in myriad ways. Music or an audio signal from an instrument can be controlled by fiddling, shaking, pressing, moving a hand through the air, or even dancing. Audio can be created, bent, sculpted, pitch shifted, distorted, or filtered with different types of tactile and motion-sensing controllers (Sutherland, 2013). Joseph A. Paradiso explains that developing technology consequently opens new possibilities for sound processing, and that even more complex ideas can be implemented easily with the tracking and mapping of almost any type of information: the temperature of the hands, the distance from a specified sensor, or pressure under the user's feet, to name a few (Paradiso 2003, p.3).

## **2 EXPERIMENTING WITH MUSIC**

*“Let’s exchange the experience, oh” -Kate Bush, ‘Running up That Hill’*

In this chapter I focus on custom sound systems, different selected techniques of both audio signal processing, and creative and experimental musical methods. I aim to provide supporting background information for the design process of my experimental project (AirLoop-pedal) in addition to introducing interesting examples of creative methods within musical processes.

### **2.1 Custom sound systems and electronic music**

The history of electronic and experimental music is full of innovations and designs that have revolutionized the music industry time and time again. These new technologies have led the way in the development of electronic instruments and musical interfaces. New musical instruments are often combinations or modifications of earlier devices, and certain characteristics and functional features have persevered throughout the history of electronic instrument design (Holmes 2008). For example, a great majority of the earliest electronic instruments were 12-tone chromatic piano keyboards, and the use of piano keyboard control even in today’s new devices is still the most widespread. In this chapter I will briefly introduce selected examples of custom sound systems and electronic instruments that have formed the fundamentals of electronic music from early 20th century until today.

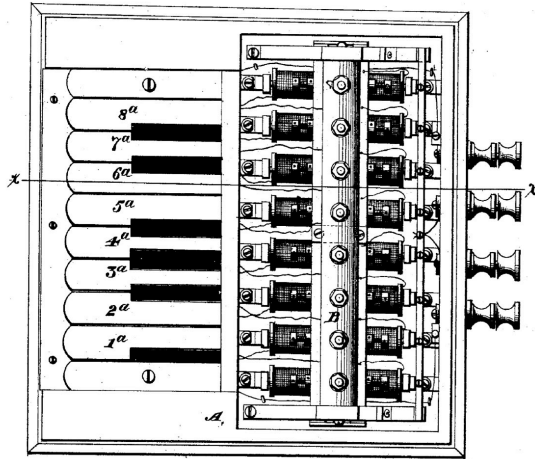
Here I would like to emphasize that my aim is not to provide any kind of a cross-section of custom sound systems and electronic instruments, but rather to simply introduce couple of examples that have been meaningful for me personally during this process. I



will introduce more examples of inspiring electronic instruments in the third chapter of my thesis.

E. GRAY.  
ELECTRO-HARMONIC TELEGRAPH.  
No. 173,618. Patented Feb. 15, 1876.

*Fig. 1.*



*[Picture 02]: Elisha Grays patent for the Singing Arc.*

### **MUSICAL TELEGRAPH (ELISHA GRAY, 1876)**

Elisha Gray's Musical Telegraph from 1876 was based on "an array of tuned electronic buzzers activated by switches on a musical keyboard" (Paradiso 1999). Musical Telegraph was the first electronic instrument, and it was controlled with a standard chromatic 12-tone keyboard.

### **SINGING ARC (WILLIAM DUDDEL, 1899)**

The main idea behind the keyboard-controlled Singing Arc was invented accidentally by William Duddel while he was working to solve London's street light humming issue. The

Singing Arc was the first fully electrical instrument (American Physical Society, APS 2014). “Such systems required daily maintenance by a small army of technicians, and arc lamps weren’t practical for indoor use, but the only real remaining problem was a constant humming noise—a byproduct of the generated sparks. An English physicist named William Duddell set out to find a solution, and ended up inventing the first fully electrical instrument” (APS 2014).

### **TRAUTONIUM (FRIEDRICH TRAUTWEIN, CA. 1929)**

The Trautonium was an electronic instrument invented by Friedrich Trautwein in the 1930s in Berlin, Germany. This monophonic instrument, based on the tones of neon oscillators and controlled with a metal plate fingerboard, was redeveloped into the Mixturtrautonium by German composer Oscar Sala (1910 - 2002) (Doepler Musikelektronik 2004; Holmes 2002, p. 65 - 66). Sala was asked to compose an entirely electronic soundtrack for Alfred Hitchcock’s *Birds* in 1963 using only the studio version of Trautonium, the Mixturtrautonium, and magnetic tape. “Even the sounds of the birds themselves were created by using this instrument. It was a highly effective technique that further reinforced the surreal elements of the film’s plot” (Holmes, p. 68). The usage of these instruments demonstrates how surprisingly versatile they were in the hands of an experienced artist (Holmes, p. 68).

## **TELHARMONIUM (THADDEUS CAHILL, 1900-1906)**

*“Cahill was the first man to have a sense for the commercial potential of electronic music as well as the means and persistence to fulfill his dream” (Holmes, p. 42).*

The Telharmonium is probably the most ambitious musical instrument ever designed and constructed. Weighing 200 000 kilograms and measuring 20 metres in length, this instrument was the first electronic instrument with a touch-sensitive polyphonic keyboard, several effects, and tone manipulation abilities. Almost 2 000 switches that connect the keyboard to the array of 145 massive rotating dynamos create different audible tones through acoustic pipes, horns, and telephone receiving devices (APS 2014; Holmes, p. 42 - 47).

## **THEREMIN (LÉON THEREMIN, EARLY 1920S)**

“The Theremin, developed in the early 1920s by the Russian physicist, cellist, and inventor Léon Theremin, was a musical instrument with a radically new free-gesture interface that foreshadowed the revolution that electronics would perpetrate in world of musical instrument design” (Paradiso, 1998). The Theremin, consisting of two LC oscillators, generates a tone and is controlled by changing the capacitance of the sensor plates in two separate antennae. The performer controls the pitch and the amplitude by moving their hands within the electromagnetic fields of the antennae on either side of the instrument (Holmes 2002, p. 49 - 51).

## **VIDEOHARP (DEAN RUBINE AND PAUL MCAVINNEY, 1990)**

The VideoHarp is not as famous as earlier-mentioned examples of custom sound systems, but it is an interesting example in new design strategies regarding motion detection-based interfaces. It is an optical tracking interface “which senses the presence and position of fingers inside the frame boundary as they block the backlighting emanating from the frame edges” (Paradiso, 1999). The movement of the fingers inside the frame is tracked, allowing several different mapping possibilities when converted to tones or sound effects through Musical Instrument Digital Interface (MIDI) (MIDI Manufacturers Association 2014).

Even though the idea of a non-tactile instrument control was demonstrated by Léon Theremin 70 years earlier, design-related thinking pertaining to these experimental instruments is different: technological development has provided a base for tracking, processing, and mapping of movement, temperature, heartbeats, or even the human voice. This information is then converted to musical tones, sound effects, or music, often through MIDI.

## 2.2 Interaction Design (IxD)

*“Engineering does not replace art in a design, it makes it possible” (Johnson, Jeff. 2010).*

Interaction design (IxD) can be described as “science-based techniques to create interactive systems satisfying specified requirements” (Johnson, pp. ix).

“Interaction Designers strive to create meaningful relationships between people and the products and services that they use, from computers to mobile devices to appliances and beyond” (IXDa, 2014).

### INTERACTION GUIDELINES

Jeff Johnson explains that the most commonly used and successful user interface or interaction guidelines, such as ‘strive for consistency’, ‘error prevention’, ‘flexibility and efficiency of use’, and ‘offer informative feedback’ work as bigger laws within interaction design that aid professionals of user-interaction design. Johnson also states, “user-interface design rules are quite similar if we ignore wording, emphasis, and the state of computer technology when each set was written” (Johnson, 2010, pp. xiii). Design rules are based on how people learn, interact, and react to different situations. Therefore, it’s easy to understand that the base of these rules is in the principles of human psychology (Johnson, 2010, pp. xiii).

## **WE PERCEIVE WHAT WE EXPECT**

“Our perception of the world around us is not a true depiction of what is actually there” (Johnson 2010, p. 1); what we see, feel, and perceive in any way is biased by our past, present, and future expectations (Johnson, 2010). Interaction design aims to utilize these learned habits, expected human gestures, and everyday routines of interaction. In other words, interaction designers aspire to respond to the expected needs of the end user. Naturally, end users tend to reflect their experiments, expectations, and learned methods when using new interfaces or instruments. Often this coaction between the end user and designer is practical and effective, but in cases like experimental music and contemporary art it can easily lead to the deficient use of an instrument. In 1937, John Cage introduced an example of this problem when describing the relationship between artists and a unique instrument: “The Theremin provided an instrument with genuinely new possibilities, Thereminists did their utmost to make the instrument sound like some old instrument, giving it a sickeningly sweet vibrato, and performing upon it, with difficulty, masterpieces from the past” (Holmes 2002, p. 51 - 52). “Although the instrument is capable of a wide variety of sound qualities, obtained by the turning of a dial, Thereminists acted as censors, giving the public those sounds they think the public will like. We are shielded from new sound experiences” (Paradiso, J. 1998). Our expectations bias our perception, and affect our working methods and interactive behaviour. Learned habits lead our ways of using a new and unique instrument to expected directions and often limit its usability.

### **2.2.1 NEW TECHNOLOGY, NEW AESTHETICS**

New innovations in musical interfaces or music technology will eventually give birth to a new aesthetics of music (Holmes, 2008; Vanttinen, 2013, p. 2). In other words, new technology enables and encourages designers and artists to carry out the old ideas in a

new way, as well as experiment with previously unused tools. “Because electronic music was reliant on technology, the music itself was going to become a testing ground for new aesthetic ideas about the art of musical sound” (Holmes, 2008, p. 350). The history of electronic music is full of innovations and new aesthetics that are born as a consequence of technological development.

Three cultural perspectives on electronic music and new technology in 1970 (Holmes, 2008, p. 351)

*1) Technology naturally leads to experimentation and eventual acceptance of new sounds, styles, and techniques for making music.*

*2) The acceptance of electronic music will succeed by comparing it to other forms of music, even if that comparison is unnecessary to accept electronic music as a musical form of its own.*

*3) Composing and listening to electronic music requires new skills.*

*In the 1950s, Johnny Burnette of the Johnny Burnette Trio and Ike Turner were among the first guitar players to discover distorted sound. The distorted guitar sound that revolutionized guitar playing a decade later (as well as the music industry of 1960s), was inadvertently created due to decayed or dislocated tubes and/or ruptured speakers. New and personal tones originating from these technical issues were adored by the young audience and the reviewers, and other performers did their best to recreate these unique tones for themselves (Millard, André 2004).*

## 2.3 Mixing the audio

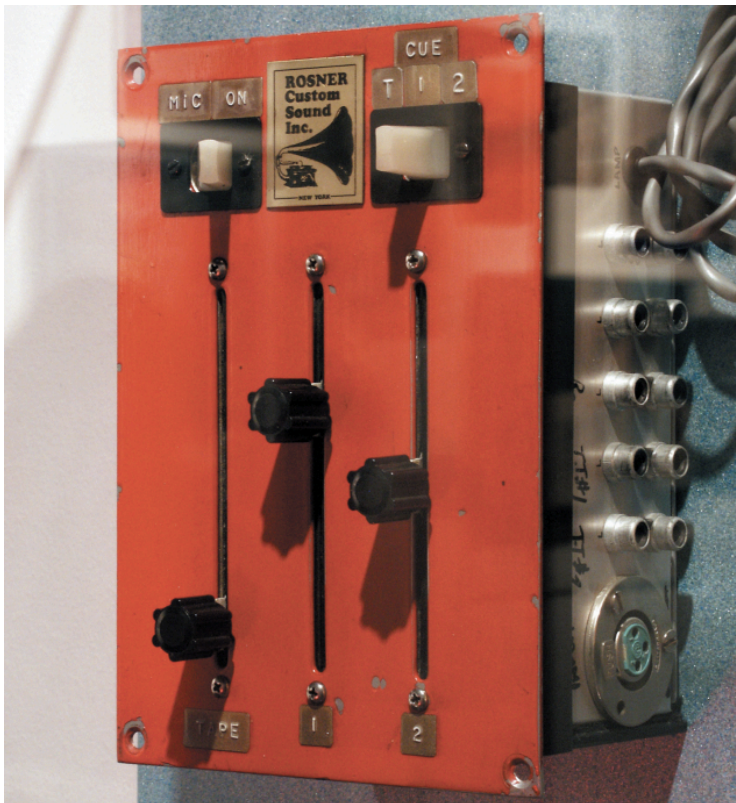
“The fundamental job of any audio mixer is to combine two or more audio signals and to allow their levels to be independently adjusted” (White, 1999, p. 13). As an example, the principle functions of a four-channel mixer are similar to the functions of AirLoop-pedal: the levels of independent audio signals can be controlled with faders, their balance can be adjusted, and they also have the capability of being muted. Before the signal enters an amplifier in the signal chain, an interesting question is firstly how to manipulate the signal between the input sockets and main output of an audio mixer (or AirLoop-pedal). Secondly, how does one control the individual mixer faders by means of motion tracking without losing the handleability of the guitar tone or interface?

Paul White states that all electronic signals, including an instrument signal from a guitar “has an optimum operating range that provides the best noise performance and the lowest distortion” (1999, p.12). If two or more guitar signals are combined without any level control, the signal will most likely overrun this operation range and has the potential to become distorted (White, 1999). In guitar pedalboard design, especially if signal splitting and combining several signals are involved, special attention has to be paid to the levels of each individual signal, as well as how they are mixed back together. Unpremeditated signal levels can easily create distortion or unpleasantly low volume levels for performers.

Crossfade is an audio mixing technique used especially among DJs, and it allows switching between two independent sound sources smoothly. “The DJ mixer crossfader was originally developed as a control for implementing smooth fades from one program source to another” (Jeffs, 1999). Crossfades maintain “constant acoustic energy” (Jeffs, 1999). In other words, the loudness of the summed signals is always the same. With a well-designed crossfade it is relatively easy to combine or switch between two



independent audio signals without changing the signal levels. For example, if signals S1 and S2 are combined into an equal leveled  $S(1+2)$ , S3 could be also combined with  $S(1+2)$  without any loudness alteration in signal  $(S(1+2)+S3)$ . With this technique, two individual crossfaders can control three sound sources without altering the level of the combined signal. In this project, I investigate the possibilities of mixing multiple (albeit separate) sound sources into a single source with digital and analog crossfaders, motion tracking and body gestures.



*[Picture 03]: "Rosie" is the first known DJ mixer (1965)*

## 2.4 Circuit bending and creative musical methods

Circuit bending refers to the manipulation and customization of electronic devices to create new sound generators, musical instruments, or music controllers. It is based on altering the circuits of electronic tools, toys, or machines by adding or changing components and combining different circuits to create distinct audible feedback. Methods for circuit bending are often described as unscientific or random, and the creative processes are based on experiential learning and finding new solutions through trial-and-error experimentation. Nicholas Collins describes the nature of the circuit bending as “freestyle sound design with a postmodern twang” (Collins 2006, p.91). This method offers a fresh perspective for musicians and music producers tired of explicit, detailed, and inevitable music production tools and rational solutions. “With its defiantly anti-theoretical stance and emphasis on modifying cheap consumer technology, bending has a natural egalitarian appeal . . . bending’s try-anything extreme experimentalism can produce wonderful results never anticipated by the original designers of the device being bent” (Collins 2006, p.91), Collins explains. Accidental findings, random variables and unexpected results are highly respected in the aesthetics of circuit bending.

An interesting example of creativity and chance is aleatoric music, by which ideas and structures “could incorporate improvisation, chance, and indeterminacy to various degrees” (Rubin, Henry J., 2005). Rubin states that aleatoric music presents traditional scores through methods of indeterminacy and other random actions. It can be based on non-musical symbols, interpretations of the performer or other “extra-musical concepts that can imaginatively be woven into a musical context” (Rubin, 2005). In 1962, composer and artist Dick Higgins asked a New Jersey police officer to fire a machine gun at blank score paper in order to create part of the series *Danger Music*. The holes were transformed into the note-heads based on their position on the sheets. The piece was then performed by an ensemble (Graham Foundation, 2014). Higgins described this aleatoric

piece as “an act of simultaneous destruction and creation” (Graham Foundation, 2014).

## **2.5 Audio signal processing and guitar signal routing**

Because the design of AirLoop-pedal is based on routing, manipulating, and mixing the guitar signal, it is essential to define basic audio signal processing terms. In this chapter I focus on guitar signal routing, mixing, signal processing terminology, and selected examples of audio effects.

Audio Signal Processing (ASP) refers to audio signal manipulation with digital or analog processing tools: processors and effects. These tools can shape, amplify, sculpt, distort, or manipulate the audio signal in accordance with the performer’s requirements. In other words, with audio signal processing tools the guitarist can, for example, build a distinctly personal guitar tone. Audio signal splitting refers to the division or duplication of an audio signal. Audio signal routing defines the path of an audio signal from an original sound source to a speaker. An example of an audio signal route: the signal from a guitar’s pickups running to a speaker through a selected chain of effects and amplifiers.

Paul White, the author of *Creative Recording 1: Effects and Processors*, distinguishes audio processing tools into two categories: 1) processors that manipulate the whole audio signal, and 2) effects that are based on mixing the unprocessed original audio signal with processed ‘wet’ signal (1999, p. 36). In other words, processors are tools which act like opaque paint, whereas effects “add a proportion of treated signal to the unprocessed signal to create their effect” (White, 1999, p.36). Equalizers, compressors, limiters, distortion devices, drivers, expanders, tremolos, and enhancers are all examples of processors. Delays, reverbs, flangers, and choruses are effects.

Signal splitting and mixing different manipulated signals are powerful and practical ways of processing guitar signal. Guitar signal is often split into two or more different amplifiers, and the selection of which output signal is activated is made with an on/off channel selector or stepless channel selector pedal. With channel selectors, the sound of the guitar can be bounced from one amp to another or played through all of the amplifiers simultaneously. Similarly, this could be executed by one guitar amplifier with a simple audio mixer after splitting and processing the signals. Split signals are routed to individual channel chains where different guitar pedal effects and processors are connected in a series, and the signal proceeds through pedals one after another. In this case all of the signals are routed after the individual signal chains to the main mixer. The main mixer then combines the signals and the consolidated signal is played through an amplifier. Controlling the main mixer could be done with analog volume and crossfade pedals, or digitally with motion detection or distance sensor tracking, for example.

### 3 EXPERIMENTING WITH CREATIVITY

*Coincidence has the ability to feed creativity.* The majority of this chapter is dedicated to the importance of spontaneity and the coincidental events that take place within the creative process. I will investigate coincidence and coincidental discoveries made with musical instruments, and how these feed musicians' creativity during a live performance or musical production. Furthermore, I discuss how these ideas can be used in the design of a musical instrument.

Based on my studies and previous experience as a sound designer, the absence of haptic response or visual cues in musical instrument substantially changes a user's experience of an instrument, and often creates interesting and coincidental situations during a performance. In the end of the chapter I introduce selected methods of movement-based instruments, and aim to find answers to the main questions around the design process of AirLoop-pedal: 1) what features of AirLoop-pedal evokes a user's creativity?, and 2) how should one approach controlling traditional guitar pedals by means of motion detection?

### 3.1 Coincidences and Creativity

*"Through experimentation you can very rapidly find a lot of things that don't work. So that points you in this direction, and you go there for a while, and find that's not working. So you go in another direction and see if that works. And by this experimentation you suddenly zero in on something that's now really talking to you. And that opens up a certain avenue and you go down there. More and more you start understanding what's working and what's not working. You begin to see the magic of it in the scene. And it's a beautiful thing." -Lynch, David (Manning 2004, p. 50)*

In musical interactions, coincidences and accidents can often feed creativity and inspiration. Within the context of this work I refer to coincidences and accidents as coincidental events or actions within the creative process that lead to new artistic discoveries. These events can be caused deliberately, such as in jazz improvisation, or they can be through aleatoric means, where details of the performance are left to chance within loosely fixed frameworks (Skowron, Zbigniew p. 43). Coincidence and accident can also refer to accidental technical discoveries of tones or sound combinations, such as Ike Turner's and Johnny Burnette's distorted guitar sound discussed in section 2.2.1.

#### COINCIDENCES AND EXPERIMENTATION

John Cage was a pioneer in exploring principles of coincidence, aleatoric processes, and other indeterminate elements of music production and composition (Manning, 2004, p. 75; Cage, 1961). In *Imaginary Landscape No. 4*, Cage composed a score for 12 independent short-wave AM-radios with precise volume level and tuning frequency notation. However, Cage did not want to control the original sound sources—those were determined by the radio stations and whatever their programs happened to be playing during the act. This piece's aleatoric element is based on the content being dependent on radio programs of that particular time and place (Harley, James 2014). These types of

techniques can be used in creative processes that explore new sound combinations, harmonies or even tunes. A simple example is recording two solo violin players improvising an identical rhythm pattern or bass line without ever hearing each other.

Free improvisation in jazz music is described as “a complex model of the highest level of interactivity” with strong influences of unpredictability and spontaneity (Winkler, Todd p. 26). Jazz improvisation is rarely based on chances, but spontaneous actions and synergy between the artists that often makes the output of the improvising ensemble unplanned and coincidental. This often works as the base for the next generation of jazz musicians, who subsequently analyze their predecessor’s works and build reformed structures and principles. The *Cellar Door Sessions* of Miles Davis at the end of 1970 is an excellent example of spontaneous, inspiring and even coincidental jazz recording. During four night-sessions in a small club in Washington, D.C., Davis recorded one of the most intense and inspiring jazz albums ever made, full of coincidences and experimental solutions that countless other jazz musicians have been trying to mimic ever since (Leone, Dominique 2006).

## COINCIDENTAL TECHNICAL DISCOVERIES

Coincidental technical discoveries have created new tones and shaped various musical styles constantly in the history of experimental music (Schader, Barry 1982; Collins 2006). Besides the aforementioned distorted guitar sounds and various tones of circuit bending techniques, there are several more interesting examples of coincidental tones and techniques. The famous seagull-effect on the guitar, initially heard in the middle section of *Echoes*, was created by Pink Floyd's guitarist David Gilmour when he "inadvertently plugged in a wah-wah guitar pedal back to front" (Mason, Nick 2004). The famous constant tune of the screaming 'seagull' was heard on several Pink Floyd's tracks in later albums, and the drummer of the band, Nick Mason, described the attitude of band's explorations in *Inside out: A Personal History of Pink Floyd* (2004):

*Sometimes great effects are the results of this kind of pure serendipity, and we were always prepared to see if something might work on a track. - - This experimentation could be seen as either a brave radicalism or an enormous waste of expensive studio time. Either way it allowed us to teach ourselves techniques which might at first be clearly nonsensical but eventually lead to something usable (Mason, Nick 2004).*

In musical interactions, accidents and coincidences are often the first tiny sparks of bigger discoveries and innovations. In interface design there are several possibilities as to how to coax the user to experiment and expose the user to coincidental actions (Johnson 2010). Based on Jeff Johnson's ideas of interface design (2010) and on my own experience as a sound designer and musician, it can be stated that coincidental discoveries usually reflect in these three ideas of design:

- 1) Changing a functional detail of an instrument or interface can create a favourable platform for coincidental discoveries. For example, removing a guitar string or mixing the order of the guitar pedal chain can easily lead to unexpected discoveries.



2) Designed randomness in an instrument's control, or lack of visual or tactile cues can lead to experimental instrument handling. Theremins and other non-tactile interfaces are good examples of instruments where the controllability is totally different from traditional instrument handling.

3) Easy access to different devices and modifications can enable the execution of intuitive ideas. Easy accessibility allows enough variables and numbers of interaction with different devices to ensure that coincidental findings occur. In the design of AirLoop-pedal I aim to encourage and utilize these coincidental findings.

## 3.2 Live performer and audience

*“Music must feel spontaneous in order to communicate a feeling to one’s emotions.”*

*(Swedien, Bruce. 2009, p. 98)*

What makes a musical interface inspiring for a performer in live performance? How can the musical interface design shape an experience for the audience? Of course there are no absolute answers to these questions—an audience’s reactions are dependent on the performer’s comprehensive act, and a performer’s inspiration could very well be sparked by an active audience. Of course there is always some sort of interaction between performer and audience; in this chapter my goal is to focus more specifically on the discoveries that make a musical interface both inspiring and creative for the performer as well as interesting for the audience.

### PERFORMER’S CREATIVITY

What features of a musical interface evoke a performer’s creativity? During my personal career as a musician, I have noticed that creative situations often arise from 1) a special collective drive of the group, 2) unexpected actions and coincidences, or 3) previously unexperienced situations, such as a new sound discovery or a different way of improvising with an instrument. The ‘collective drive of the group’ refers to situations where the effect of the performers’ group work, actions and reactions, and strengthened team spirit lead to the momentary peak of confidence, energy, motivation, and curiosity. Interrelationships between artists (as well as audience) are essential factors in the research of the live performer’s creativity, but in this work I will focus more on the relationship between the interface and performer, and uniquely new creative situations and coincidences.

A certain amount of controllability, skills for controlling the instrument, and a means of reacting spontaneously are also essential elements in controlling the musical interface. Therefore, an important design issue is knowing how to balance controllability with designed coincidences. Based on my own experience, experiments with versatile effects and processors often inflame curiosity and inspiration, and this can easily change the direction of the whole composition process or performance. On a related note, multimedia designer and artist Jan Willem Huisman states that “curiosity and playfulness are deeply embedded in our mind and feed the urge for learning and exploring” (2014). So the essential question at hand is how to find harmony between the possibility for not-yet-experienced sounds, playfulness, and sufficient controllability of the interface. During this project I aim to find answers to these questions through different techniques and prototypes of AirLoop-pedal, and will concentrate more in regards to the results in the fourth chapter.

## **EXPERIENCE OF THE AUDIENCE**

*“One of the main challenges facing the designer of musical interface users in performance is to produce mappings that, at least periodically, strip away layers of abstraction, allowing the audience to smell the digital sweat as the artist pushes their instrument to the edge.” (Paradiso, O’Modhrain. 2003, p. 347)*

An audience’s experience in a live performance is “a complex set of interrelationships between artists, audience members, instruments and the environment lead to the senses of community, presence, tension, uniqueness and admiration felt during the show”, states Jonathan David Hook in his doctoral thesis *Interaction Design for Live Performance* (2013). Generally there must be a connection between the audience and performer which is based on understanding the actions and consequences of the performer or interface in order to provide and maintain feelings of community, admiration, or tension (Murray-Browne, Tim 2012; Paradiso 1999). As media art professor and artist Joseph A. Paradiso

explains, “an artist playing an acoustic instrument usually exploits a mental model that the audience has of the instrument’s action-to-response characteristics, allowing virtuosity to be readily appreciated” (1999, s. 4). However, the lack of understanding how interfaces or musical instruments work (and subsequently what the performer is actually doing) can easily cause confusion and weaken the interest towards the performance (Paradiso, 1999).

In conclusion, how can the musical interface design enhance an experience for the audience? As stated before, understanding and perceiving how the performer is controlling or interacting with the device are fundamental issues in musical interface design for live performance. Paradiso also emphasizes the importance of a strong connection between the audience, performer, and musical interface: “One aspect of a musical performance that is often overlooked in the design of electronic musical instruments is that of the audience’s understanding of how the instrument is played” (1999). These problems in design often emerge with hidden interfaces, overly complex mapping structures, or sensors without any visual cues for the audience (such as pressure, temperature, or heartbeat sensors).

### **3.3 Movement-based digital instruments**

People are craving for new means by which they can express themselves musically; movement-based digital instruments are excellent and diverse tools for creative music production and live performance. With the miniaturization of computers and sensors—as well as the revolution of wireless technology—more and more amazing new innovations are constantly springing up.

Movement-based digital instruments use diverse features of movement as an input for controlling the digital instruments. These interfaces detect movement 1) by a controller held in the user's hand, 2) by wearable sensors in the user's clothing or on the user's body or 3) by non-contact sensing based on camera tracking, distance or light sensors, ultrasonic movement tracking, or other methods of kinetic sensing. This tracked information is then mapped to the actions of a digital instrument. As Paradiso explains, “the term mapping relates to the question of matching the capabilities of the human sensorimotor system to the parameter space of the instrument being played, in order to provide the performer with appropriate control of music's four fundamental elements—time, pitch, timbre and amplitude” (Paradiso 2003, p.3).

For movement-based instruments, it is too complex to define all-encompassing instrument category standards simply because there are so many various technical solutions, applications, practitioners, developers, and methods of using these devices. Additionally, the rapid development of non-tactile technology and the unpredictable future of said devices gives birth to many different interpretations of categorical definitions, depending on whose viewpoint one chooses. Joseph A. Paradiso and Kalle Mäntsälä categorize non-tactile instruments from a user's perspective into: 1) batons, 2) wearables, and 3) non-contact sensing interfaces (Mäntsälä 2009, Paradiso 1999).

## BATONS

Batons are hand-held controllers that track information pertaining to acceleration, location, speed, pressure, and bending. Additionally, even information such as temperature, a pulse from the user's hand, or compass directions can be utilized (Mäntsälä, 2009). Batons could be described as a mixture of a remote control and a conductor's baton, and they also enable haptic feedback for the user. Max Mathews' Radio Baton (1970), the Lightning II Controller from Buchla & Associates, Joseph Paradiso's and Teresa Marrin's Digital Baton (1997), and the Nintendo Wii (2004) are all good examples of revolutionary interface design. Naturally, many of the smartphone and tablet applications of today provide the same type of interface or musical instrument features.



*[Picture 4]: Digital music pioneer Max Mathews (1926 – 2011) with the Radio Baton.*

## WEARABLES

With wearable digital instruments, the sensors are placed in the clothing or on the body of a user. Examples include textiles or clothes embedded with electronics, head-mounted computers, pedometers, heart straps, and monitoring rings (Tang, 2007). These can also be used during physical activity. Wearable devices can track and detect information such as posture, movement, acceleration, pressure, or even biosignals such as body temperature, heart rate, respiration rate, and skin conductivity (Tang, p. 287).

History is full of interesting examples of wearable electronics and wearable musical instruments, but here are listed some examples which are of particular interest to me:

*1) Michel Waisvisz introduced the revolutionary wearable MIDI-controller “The Hands” in concert in the Amsterdam Concertgebouw in June 1984 (crackle.org). Two wearable claws worked as controllers for a special programmed Yamaha DX-7 synthesizer.*

*2) “Yamaha Miburi”, commercially released in 1994, “uses a sensor to calculate the position and orientation of various peripheral devices that attach to multiple parts of the body” (Protomusic.com, 2014).*



*[Picture 05]: Yamaha Miburi, 1994.*

3) *“Gypsy Midi motion capture MIDI controller” from Sonalog in 2006 that was “modeled on the human skeletal form using rotational sensors at the joints.” It “plugs into a MIDI interface and arm movements are converted into a real-time stream of MIDI data” (Hanlon, Mike, 2006).*

## **NON-CONTACT SENSING INSTRUMENTS**

Non-contact sensing musical instruments are based on the tracking of the human body’s movements by way of cameras, infrared light, ultrasonic movement tracking devices, or other motion tracking implementation. Non-contact musical instruments differ from the rest of the instruments considerably, namely because they lack tactile feedback. When non-tactile interfaces respond to the position or movement of arms, feet, or the whole body without any physical connection to the interface, it is challenging for instrument designers to provide sufficient (if any) natural feedback to the player.

The absence of haptic response or visual cues substantially changes the user experience of an instrument. Consequently, non-contact musical instruments are often harder to control accurately, and can lead to unexpected situations and surprising reactions from a performer. The control of the AirLoop-pedal is based on sonic feedback rather than visual or tactile cues. In a live performance this clearly adds an extra random factor to the usability, and it easily leads to new musical discoveries, methods of playing, and controlling the sound.

*Some other interesting examples of non-contact digital instruments:*

*Air Piano, Kinect, iRing, Cubase iC Air, Geco, and Leap Motion*



### 3.4 Guitar signal processing and motion-based interfaces

*"I hooked up my accelerator pedal in my car to my brake lights. I hit the gas, people behind me stop, and I'm gone." –Steven Wright*

Electric guitarists often manipulate, process, and modify the sound of their instrument with guitar effect pedals attached to a pedalboard on the floor. These analog or digital effects are controlled by the foot with simple on/off-switches, volume pedals, or expression pedals which can be programmed to change the level of a selected parameter of a single guitar effect (Willet, Wesley 2008, 1-3; Remignanti, Jesse). Expression pedals enable the stepless adjustment of a selected parameter, such as the delay time of an echo or the speed of a tremolo effect, whereas switches only allow a player to turn the selected effect on or off. Expression pedals, as well as guitar volume pedals, usually work with the same principle as the accelerator pedal of a car or a church organ's volume pedal: when pushed down, the level of the pedal reaches the maximum and, in contrast, when raised up, it diminishes. The advantages of these types of traditional guitar effect pedals are a matter of being easily usable and accurate. The drawback is that the player is limited to operating only one pedal or switch at a time.

*"In recent years, many effects unit manufacturers have moved away from manual effect controls to systems where effects are controlled automatically without much input from the user. While some interesting sounds can be created in the manner, the user can feel somewhat removed and out of control." (Remignanti, Jesse, Source Audio LLC)*

Guitar effects with touchscreens allow controlling two or more variables of the selected effect simultaneously. However, the changing these controls must be made with the hand, which can weaken the control of the instrument itself. Brian Eno and Nels Cline (Wilco) have used the Kaoss Pad both on albums and in live performances for controlling delays, pitch shift, and various filters. Matthew Bellamy (MUSE) uses the touchpad attached to

his MB-1 guitar for maintaining the instrument control when changing the effect parameters. A Hot Hand USB wireless controller attached to a user's wrist, instrument, or any other body part allows the adjustments of modulation, filter sweeps, or distortion levels so that the "accelerometer translates motion into a dynamic and precise expression signal" (Source Audio, 2014); motion tracking information is then applied to different effect parameters. Another example is the Sensor Wah Wah by Seemann Custom that enables the control of a filter-sweep effect via a proximity sensor placed in the front of the pedal. Controlling the effect is done by moving the foot in the air above the pedal.



*[Picture 06]: Brian Eno Playing Bass, 1980.*

There are a variety of different guitar effect pedals and uncountable ways of controlling them. The broader and trickier the combination of effect pedals, the more it starts to behave like an independent instrument. Therefore, many guitarists feel that pedalboards

are in and of themselves customized personal instruments that require practice and new skills. Pedalboards are not only for manipulation and processing guitar tone, but also an effective tool to explore new ways of musical interpretation and creativity.

### 1. PEDAL BOARD SPIEL (2005), NELS CLINE (WILCO)



[Picture 07]: Pedal Board Spiel, 2005 (Cline, Nels 2005).

- 1) Boss tuner
- 2) Voodoo Lab Pedal Power II
- 3) Fulltone Deja Vibe the little one, non-stereo)
- 4) Digitech Whammy Pedal (the original model)
- 5) Z-Vex Fuzz Factory
- 6) Ernie Ball volume pedal (I've managed to break 5 of these things over the years, but still I persist...)
- 7) Crowther Audio Hot Cake overdrive
- 8) Boss CS3 Compressor
- 9) Boss Vibrato Pedal
- 10) Fulltone '69 Fuzz
- 11) Klon Centaur overdrive
- 12) ProCo Rat distortion (modified)
- 13) Boss DD-2 digital delay

*\* floating on and off the pedal planet:*

*Cry Baby wah-wah (not pictured)*

*14) Electro Harmonix The POG*

*15) Block of wood: custom made (for my foot during lap steel moments)*

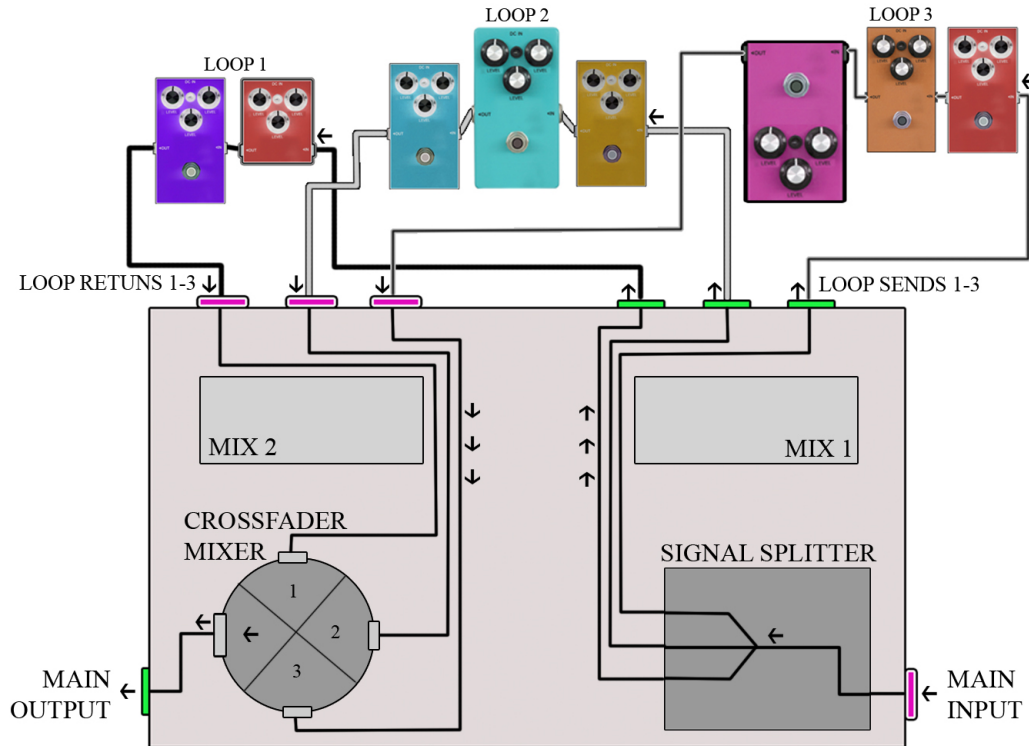
## **2. MANSON MB-1, MATTHEW BELLAMY (MUSE) & KAOSS PAD**



*[Picture 08]: Manson MB-1 (Matthew Bellamy signature guitar).*

## 4 AIRLOOP-PEDAL

AirLoop-pedal is a non-contact signal processing device for guitar that is designed to control guitar pedal loops through motion detection. AirLoop-pedal is: 1) compatible with standard analog pedals with a latency-free analog guitar signal chain, 2) usable as a standalone device, and 3) controllable with movement tracking, still allowing versatile but accurate control of the device.



[PICTURE 09]: The signal routing of AirLoop-pedal.

In this chapter I will begin by introducing the main functions of AirLoop-pedal: 1) connecting, and 2) controlling. By first outlining these functions I aim to guide the reader to a better understanding of the design process as a whole. I will then describe the design process, which is comprised of 1) the original idea, 2) required features, and 3) technical solutions of individual functional units. In the fifth chapter [*Conclusions*] I evaluate how the function of AirLoop-pedal corresponds to the required features listed above, together with my ideas of usability and design. I also aim to compare the functions of AirLoop-pedal to preexisting guitar signal processing devices, as well as introduce a few new improvement ideas for the next version of AirLoop-pedal (prototype #4).

## **4.1 Functioning of AirLoop-pedal**

### **CONNECTING**

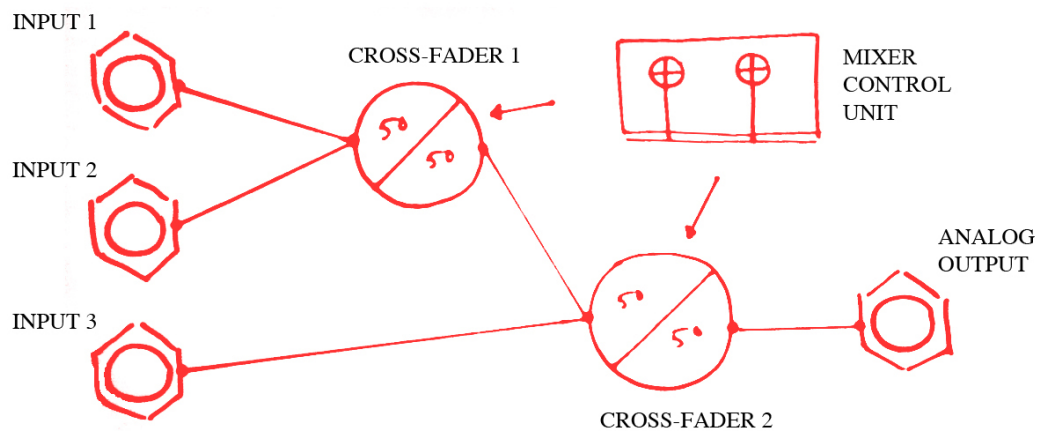
Like other traditional guitar pedals, AirLoop-pedal is designed to sit on the floor and be controlled by foot. Its physical size is 7 x 17 x 25 cm (height/width/depth). The device has standard input (main input) and output (main output) 6,3 mm mono jacks, by which the guitar (input) and amplifier (output) are connected. On the backside, AirLoop-pedal has three pairs of send (L1, L2, and L3) and return (R1, R2, and R3) 6,3 mm mono jacks which are used for creating individual guitar pedal chains ('Loops') [Picture 09]. All of the signals from the send outputs (L1-L3) are buffered, noise-free duplicates of the original input signal. If send outputs are not connected, the signal of that particular chain is automatically directed to the return of the same guitar pedal chain. Processed signals with Loops 1-3 are hereby simply called signals 1-3 (S1-S3).

AirLoop-pedal is powered by a standard guitar pedal AC adaptor.

## CONTROLLING

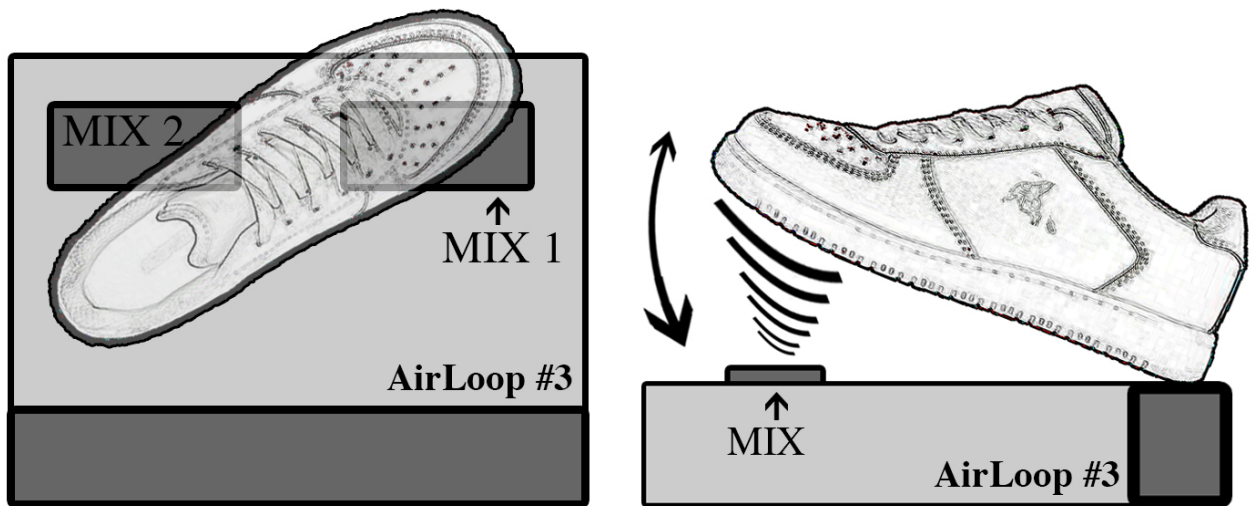
The two main controlling sensors (Mix 1 and Mix 2) of the device are controlled with the foot. With a stepless function range of 15 cm directly above the infrared sensors, the user is able to control the volume balance between individual processed signals.

The basic idea of controlling AirLoop-pedal is simple: by default only the signal from Loop 1 (S1) goes through the pedal, and mixer controllers (Mix 1 and Mix 2) control the proportion of the signals from Loops 2 and 3. Mixer controllers function in much the same way as invisible car accelerator pedals. When the Mix 1 ‘pedal’ is pushed down, the proportion of Loop 2 increases, and with the same basics, Mix 2 controls the signal from Loop 3.



[PICTURE 10]: Sketch of a Crossfader mixer with 3 inputs for S1 – S3, and 2 individual crossfaders controlled by Mix 1 and Mix 2.

Controlling Mix 1 or 2 is done either with the heel on the side bar of the device by lifting the toes [Picture 10, right], or by moving the whole foot freely above the Mixes [Picture 10, left]. When the foot is in the 0 - 1 cm range above the Mix, the level of Mix 1 or 2 is at its maximum (10), and diminishes towards 0 as the foot is moved toward the activation point (15 cm above Mix 1 or 2). This enables full control of both of the Mixes without touching the device. Interesting sound combinations occur easily when both Mixes are controlled at the same time.



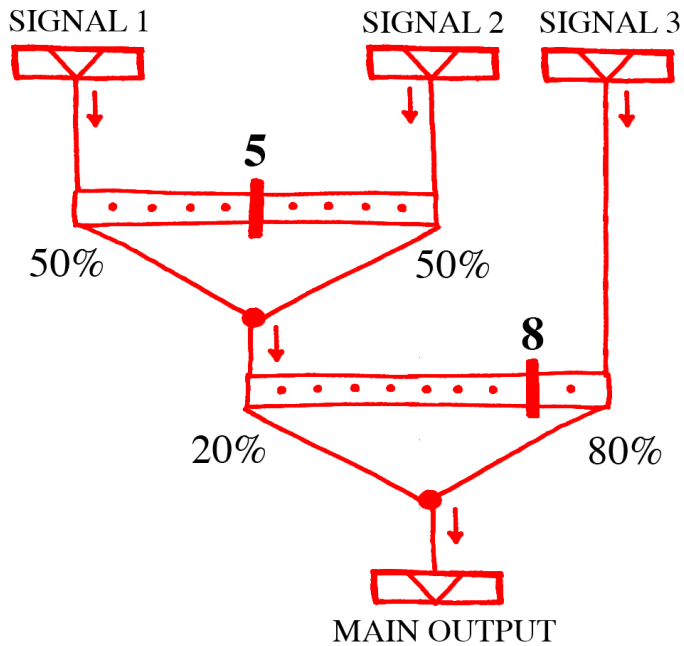
[Picture 10]: Controlling AirLoop-pedal. Both Mixes can be controlled simultaneously with a slanted foot (left picture).



### CROSSFACER MIXER CONTROLLING EXAMPLE,

*Two individual crossfaders controlling the 'Crossfader Mixer'.*

*Mix 1 controls the balance between S1 and S2, and Mix 2 controls the balance between S3 in addition to the consolidated combination of S1 and S2. When the foot is outside of the activation range (0 - 15cm), Mixes 1 or 2 are not activated, the signal from Loop 1 is at the maximum amplitude level, and Loops 2 and 3 are muted.*



[PICTURE11]: Sketch of a Crossfader mixer.

*If Mix 1 is on '5' (0 - 10 range) and Mix 2 is on '8', the output signal is 20 / 80% combination of S(1+2) and S3 with the total balance of 10/10/80% (S1/S2/S3).*

#### 4.2.1 ORIGINAL IDEA

The original idea of AirLoop-pedal was based on the combination of my passion for electric guitars and the diverse possibility that Media Lab Helsinki in the Department of Media has offered me throughout the duration of my studies.

During my career as a guitarist and music producer, I have experimented and performed with a host of different guitars, pickup settings, amplifiers, guitar pedals, and processors during hundreds of live performances, studio sessions, rehearsals, and jams. My methods of achieving guitar tones have always been experimental—I tend to focus on exploring by simply trying different combinations of guitar pedals and blending their techniques. I tend to think of the guitar pedalboard as an instrument unto itself, and altering it subsequently changes the nature of my playing (for better or worse). Occasionally even the most disastrous experiments have led me to quite interesting discoveries.

Media Lab Helsinki has offered a fantastic platform for experiments with sound design, sensors, processors and sounds effects. During my studies in the Master's degree programme in Sound in New Media I have had a chance to partake in experimental data flow programming projects with motion detection, sensor tracking, and interface design. Also beneficial was the chance to share and exchange ideas and visions with the teachers, staff, other students within Media Lab, as well as people from other departments of the School of Arts, Design, and Architecture.

The first idea of AirLoop-pedal was likely born while exploring different stereo bass guitar techniques for the production of *Riverdog Samson: Riverdog Samson Album* (2011). The split bass signal (duplicated with Boss TU-2 tuner) was initially routed through individual pedals chains to separate amplifiers. The blend option of the guitar volume pedal (Ibanez VL10) enabled a smooth crossfade of processed individual signals, which could be sent to the different inputs of a single amplifier. I later began to

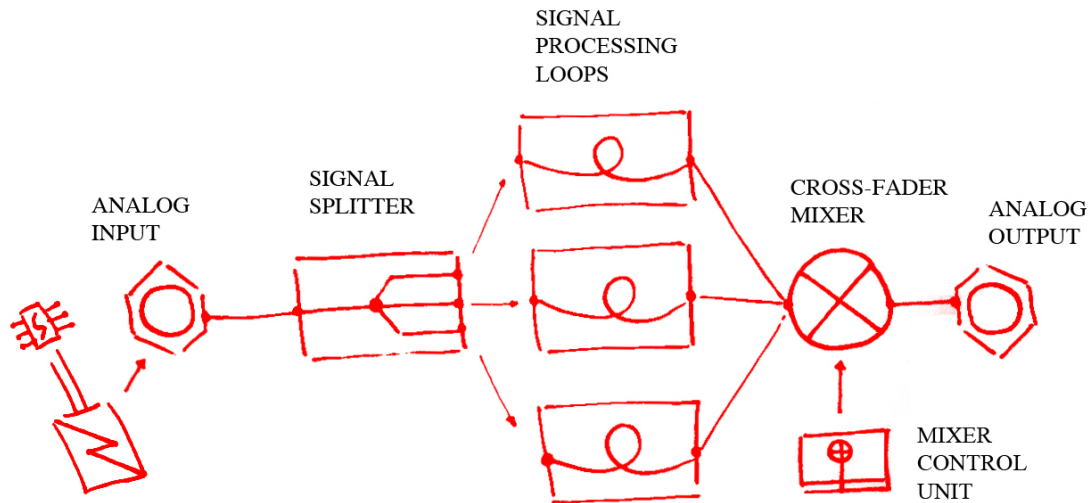
investigate different methods of controlling the crossfader pedal and search for possibilities of applying the idea to three or more individual signal chains.

#### **4.2.2 REQUIRED FEATURES**

Usability as a standalone pedal
Compatibility with standard guitar pedals
Device does not modify the signal when inactive
Motion detection control with two independent sensors (or trackers)
Latency-free guitar signal chain
Entirely analog guitar signal chain
Suitable size for a standard guitar pedal board—equal or less than 7 x 17 x 30 cm (height/depth/width)

### 4.3 Technical solutions of AirLoop-pedal

The most essential parts (the main processing units) of AirLoop-pedal are a) the signal splitter that duplicates the original guitar signal equally into three individual analog signals, b) the analog processing loop with physical send and return mono (6,3 mm) jacks, c) a crossfader mixer that blends three individual signals into a single mono signal of equal amplitude, and d) the motion detection unit that tracks and maps the information from the distance sensors and controls the analog crossfaders digitally.



[Picture 12]: Early design sketch of the AirLoop-pedal.

#### MAIN PROCESSING UNITS:

##### 1) SIGNAL SPLITTER

[Appendix 1: AirLoop-pedal (#2 and #3) Active Guitar Signal Splitter schematic diagram.]

In order to control individual guitar signal chain levels, the original signal (S) from the

guitar needs to be split (duplicated) with a buffered active guitar signal splitter into three individual signals (S1, S2 and S3) of equal amplitude.

The electronic design of the splitter is based on the 4-way active guitar ‘splitter’, or distribution amplifier (Jensen Transformers, 1996).

## **2) PROCESSING LOOP**

AirLoop-pedal has three pairs of loop send (L1, L2 and L3) and return (R1, R2 and R3) 6,3 mm mono sockets that are used for creating individual guitar pedal chains. As mentioned before, if send outputs are not connected, then the signal of that particular chain is automatically directed to the return of the same guitar pedal chain. Almost all standard guitar pedals are connected with a standard 6,3 mm guitar plug; I specifically designed AirLoop-pedal to be compatible with the majority of pedals by using this standard size.

AirLoop-pedal also functions as a guitar signal splitter when loop send outputs are connected directly to amplifiers or other devices.

## **3) CROSSFADER MIXER**

*[Appendix 2: Crossfader mixer of AirLoop-pedal (Prototypes #2 and #3) schematic diagram.]*

The crossfader mixer of AirLoop-pedal is based on two independent analog blend faders that are controlled by changing the resistance value of the digital potentiometers. The guitar signal circuit of this mixer is fully analog.

Input signals S1 and S2 are combined into an equally leveled  $S(1+2)$ , and in turn S3 is also combined with  $S(1+2)$  without altering the signal amplitude ( $S(1+2) + S3$ ).

Accordingly, two individual crossfaders control three sound sources without altering the

level of the combined signal.

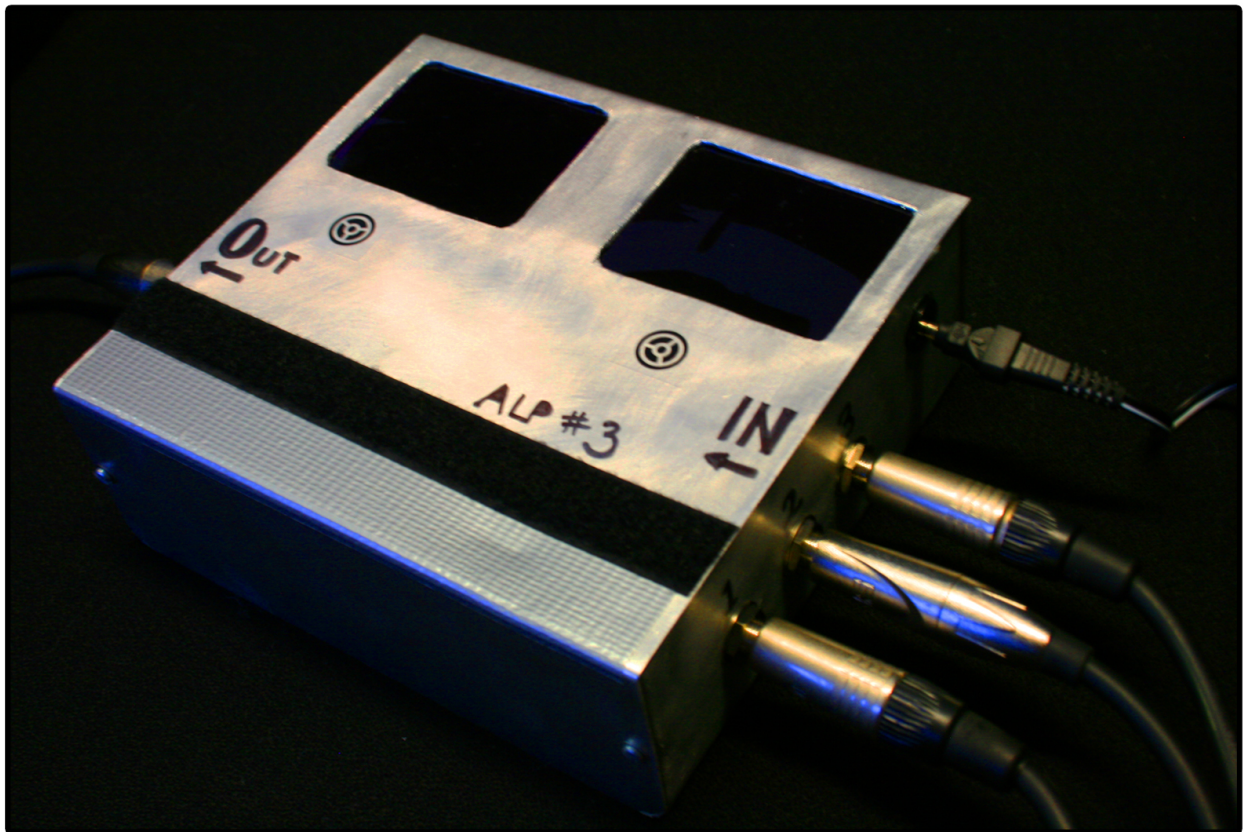
#### **4) MIXER CONTROL UNIT**

The mixer control unit has two individual infrared sensors that are programmed to work from the range of 0 to 15 cm above the device. Values from the infrared sensors (0 – 10) are read from Arduino analog inputs using a Sketch program, which is executed in C programming language. The analog values are converted to digital data, and an SPI (serial peripheral interface) connection is used to control digital potentiometer resistance values on the blender circuit. In other words, the crossfaders of the ‘Crossfader Mixer’ are controlled with individual distance sensors. Communication between the sensor—an Arduino One Microcontroller Module—and a digital blend potentiometer is based on the SPI protocol introduced in *Arduino Learning*: “Controlling a Digital Potentiometer Using SPI” (2014).

The decision to use infrared distance sensors was based on good results from personal experiences experimenting with both infrared and ultrasonic sensors. I chose infrared sensors for this project because they have more a stable response and better working range. My preference for using an Arduino Uno and Serial Peripheral Interface (SPI) protocol was based on similar reasons: previous experience, proof of positive results, and easy accessibility. Because of these decisions I am able to concentrate the resources of the project on usability, signal processing solutions, and physical design.

I would like to emphasize that this project is an ongoing experimental process, and the precise sensor testing and data flow controlling, as well as mapping the sensor information, is left to the next phase of the project due to limits of time and resources. My professional know-how in this process concerns the design elements of AirLoop-pedal regarding innovative signal routing and guitar signal processing, and I aim to focus the majority of project’s resources in these areas. There are hundreds of ways of mapping

sensor information, calibrating and scaling the data that controls the digital potentiometers of the blend circuit, and building an electronic crossfade mixer with digital potentiometers. Those functions will be developed further and tested in the next phase of the project with the help of professionals specialized in these areas. At the present moment within the development process, the most important technical information is that the design is working and I am therefore able to test and develop it further.



*[Picture 13]: AirLoop-pedal, prototype (ALP #3). Note: in the prototype #3 the signal splitter is a physically separate unit. Three inputs in the picture are 'Loop returns'.*

## 5 CONCLUSION

### 5.1 Evaluation and future development of AirLoop-pedal

For the future development of the device, it is essential to ponder these questions about functioning and design of AirLoop-pedal:

- 1) How does the design of AirLoop-pedal work in practice, and what new possibilities does it provide compared to the preexisting guitar signal processing devices?
- 2) What is important to consider for the future development of AirLoop-pedal?
- 3) How does the design of AirLoop-pedal correspond to this Master's thesis' original statements of creativity, new technical solutions, and musical interface design?

Motion detection guitar pedals that are able to control analog signal chains are quite exceptional, and even the basic idea of controlling multiple individual analog guitar signals with two or more individual crossfaders has been explored very little. There are various studies and commercial products of analog guitar pedal chain controllers, analog guitar signal splitters, and digital multiprocessors for guitars with several different routing and mixing possibilities. However, none of the products I have used, seen, or even heard of throughout my career or during this Master's thesis process provide the features of AirLoop-pedal mentioned earlier in *Required features 4.2.2*. The knowledge gained during this process provides significant information and new design methods with respect to creative guitar signal routing and processing.



Derived from many hours of testing the different AirLoop-pedal prototypes, I have listed the main advantages and deficiencies of AirLoop-pedal, in addition to future development ideas for the device. These discoveries and facts of the already functioning AirLoop-pedal prototype #3 answer partly to the questions introduced earlier, but new prototypes (in addition to user testing and a range of studies) are needed in order to develop AirLoop-pedal further. Development-related questions such as how professionals, amateurs, and first-time players explore the offered signal processing possibilities would yield insightful information that would certainly help shape future versions of AirLoop-pedal.

#### **ADVANTAGES**

The design of AirLoop-pedal offers easy controllability, and is compatible with standard guitar pedals and simple connecting possibilities.
It provides versatile and reasonably accurate controlling of 'Mixes 1 and 2'.
It creates interesting unplanned sound combinations.
It enables easy exploring of creative musical methods, thus providing an inspiring and playful guitar signal processing platform.
It functions also as a guitar signal splitter with 'Loop send 1-3' outputs.
'Loop returns' can be used as inputs for other sound sources. For example: connecting three individual performers to 'Loop returns 1-3'.
It can be used with any type of sensors that provide analog feedback.

## DEFICIENCIES

The controlling unit may lose playability over time due to scratches or dirt.
It is not possible to store or freeze a selected sound combination.
It does not provide any visual feedback.
Without proper electric isolation of 'Sensor Control Unit' and 'Crossfader Mixer', unwanted noises may occur with digitally controlled crossfaders.
The construction costs of a signal splitter unit with proper isolation are relatively high (250 - 350 euros). Note: in the AirLoop-pedal prototype #3 the signal splitter is a physically separate unit.

## DEVELOPMENT IDEAS & NOTIFICATIONS

Freeze option enabling the restoration of discovered sound combinations in the form of presets.
Optional individual outputs for blended signals that provides smooth sweeping between three guitar amplifiers.
Servo-motored controlling of 'Crossfader mixer' would provide a cost-effective, 100% electric isolation between 'Sensor Control Unit' and 'Crossfader Mixer'.
Phase shifting option (e.g. 180° or 2 x 90°) for 'Loop returns' of each channel. (Altering phases between signals (S1-S3) creates different sound combinations)
On/Off switch, providing possibility to turn <b>on</b> or <b>off</b> one or both 'Mixes'.

## 5.2 Overview of the Process

The goal of my Master's thesis has been to investigate new creative methods for guitar signal manipulation and guitar pedal controlling, and ultimately to design and develop functional prototype of AirLoop-pedal. During my work process I have also examined how new technology creates new possibilities for creative music, with the support of my two main statements: 1) **new technology creates new aesthetics of music**, and 2) **coincidences have the ability to feed creativity**.

During this somewhat experimental design project I have observed that my statements and experiments in music have not only served as scientific endorsement for the design methods used in the AirLoop-pedal, but they have also often expanded my curiosity for exploring different methods with these prototypes, sensors, signal routing, and guitar signal processing. A similar example: the production idea where the tape was cut into pieces, thrown in the air, picked up, and spliced back together in random order during the recordings of Beatles' *Being For The Benefit of Mr. Kite* in 1967 (Ryan, and Kehew, Recording the Beatles, 2009). This particular idea did not only give me valuable information of this exceptional technique, but also inspired me to dive deeper with both studying and creating experimental music.

I suspect that I have discovered far more questions than answers during this process, but that demonstrates precisely what is essential in a successful experimental process. The outcome of the project is that I have successfully designed and created a functional prototype of AirLoop-pedal that corresponds with the requirements laid out during the design process. The design of AirLoop-pedal provides valuable new insight into guitar signal processing and standard guitar pedals can be creatively used. This process definitely laid out grounds for future research and development of the device. I have also been able to formulate new ideas for the creative non-contact control of an analog audio signal, and personally discovered various new and inspiring methods for manipulating

my guitar tone while performing.

Additionally, the process has provided me a great deal of valuable information concerning the practical methods of organizing a design project. Timetabling, communicating with technical supervisors and engineers, outlining and detailing a budget, or developing effective project planning could easily become difficult challenges in an experimental project such as this one. During this process I have noticed that flexibility in both schedules and communication with other participants of the project was crucial in being able to fix challenges in the design or implementation of the product.

The development of AirLoop-pedal continues, and naturally I will utilize the information of design and creative methods achieved during this process for future development. Lastly, by introducing the new goals of the project I aim to close this circle, and start a fresh new round by: 1) finding partners for the next phase of the project, and 2) finalizing a model of AirLoop-pedal that is marketable and ready for patenting.

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*[Picture 10]: Ville Wallenius (2013). Sketch of a Crossfader mixer.*

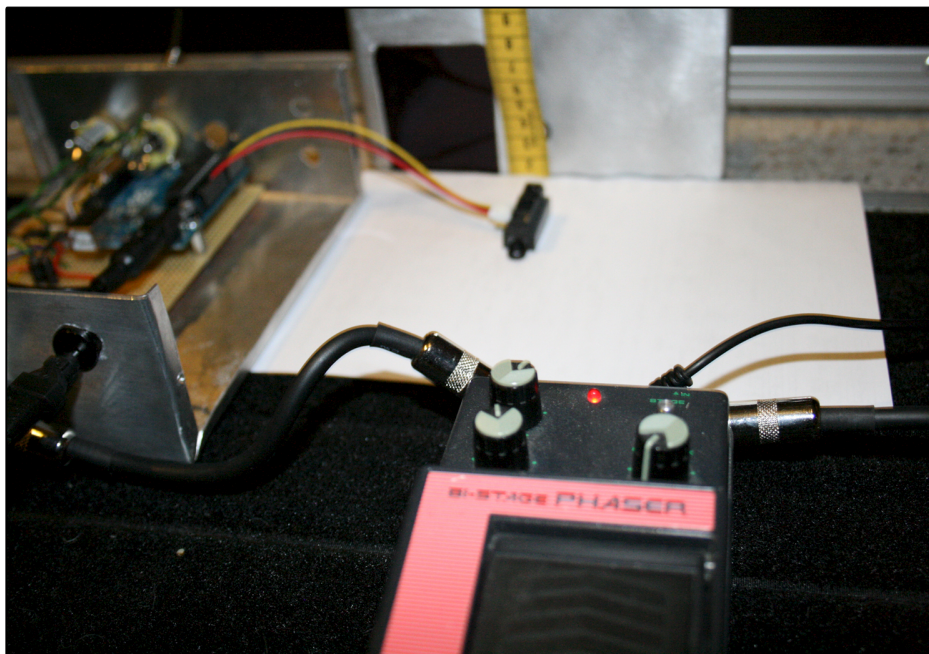
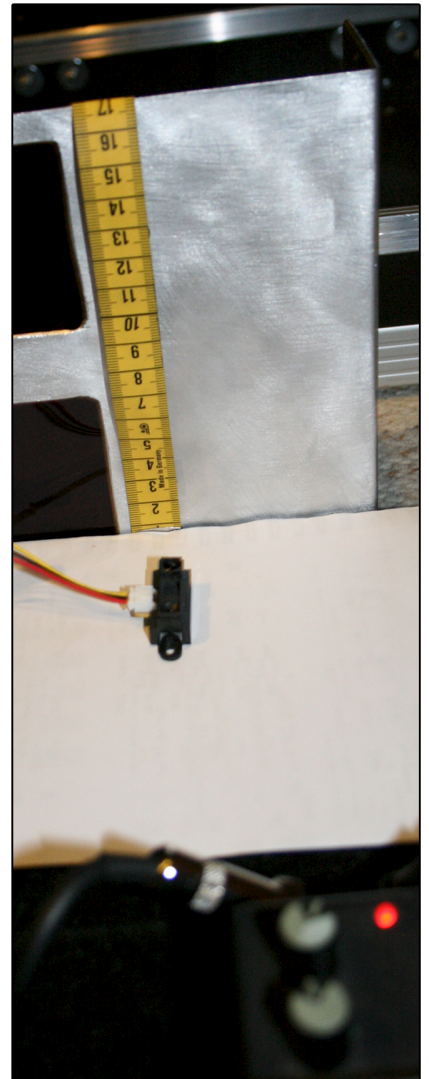
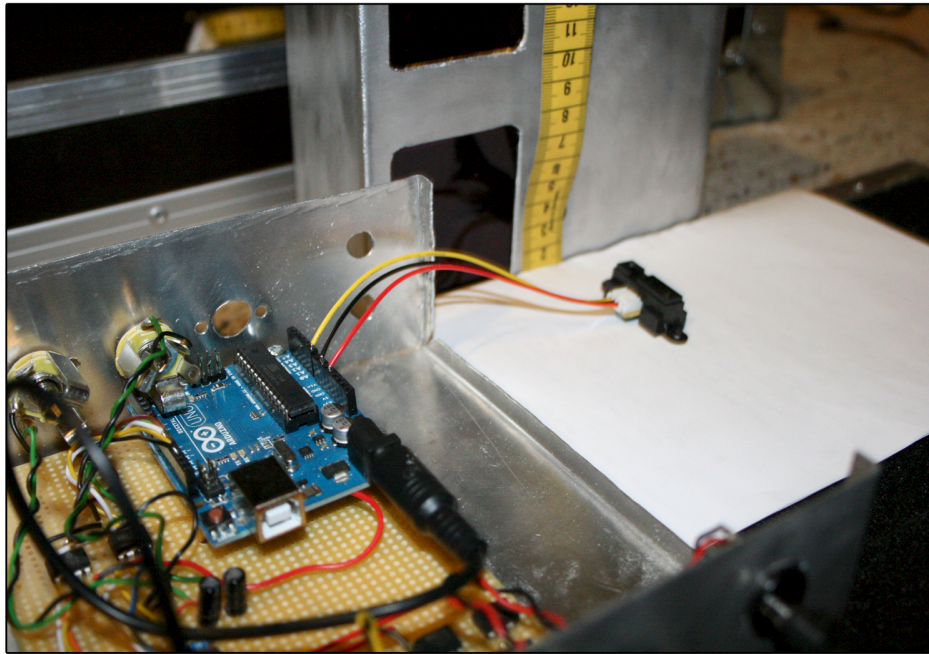
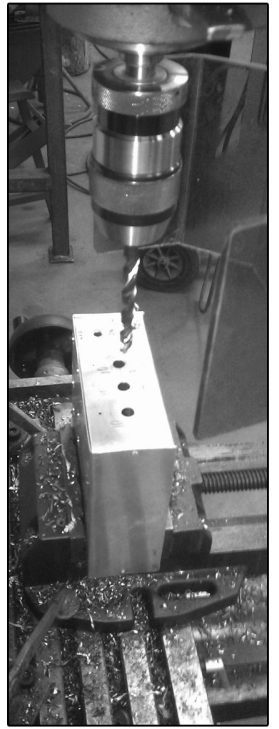
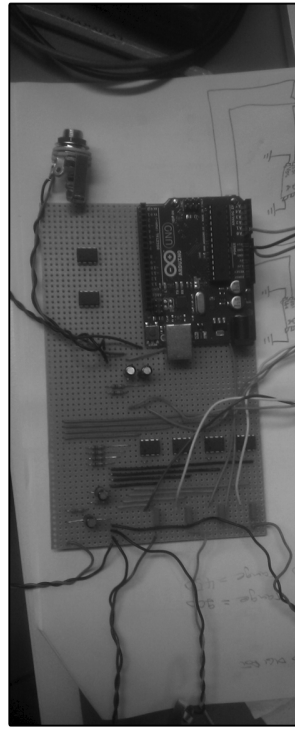
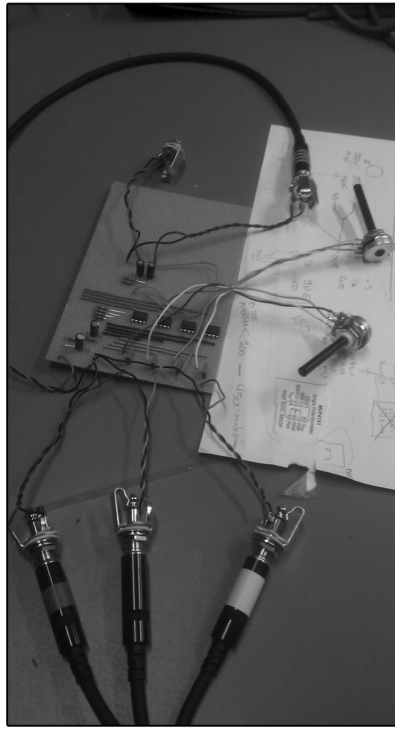
*[Picture 11]: Ville Wallenius (2013). Crossfader Mixer Example.*

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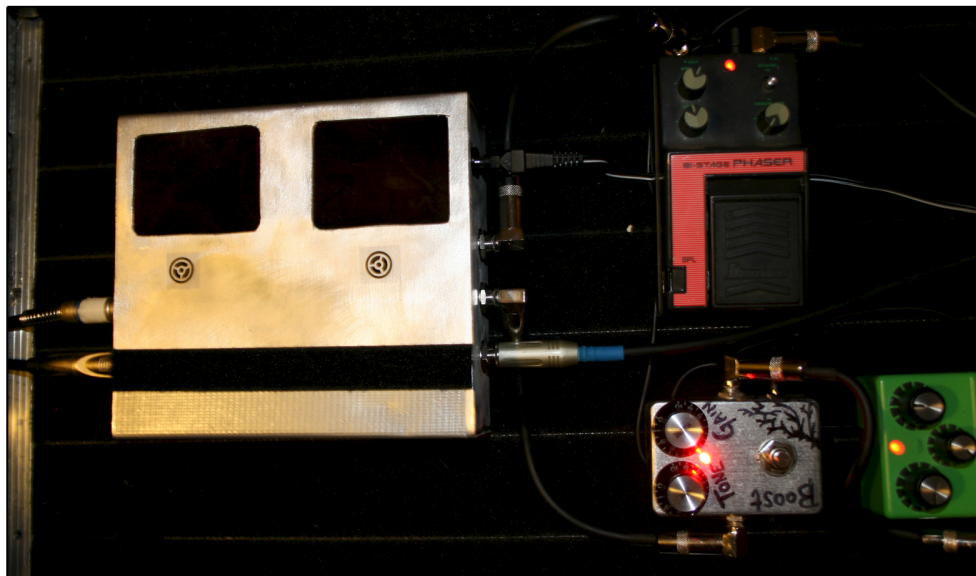
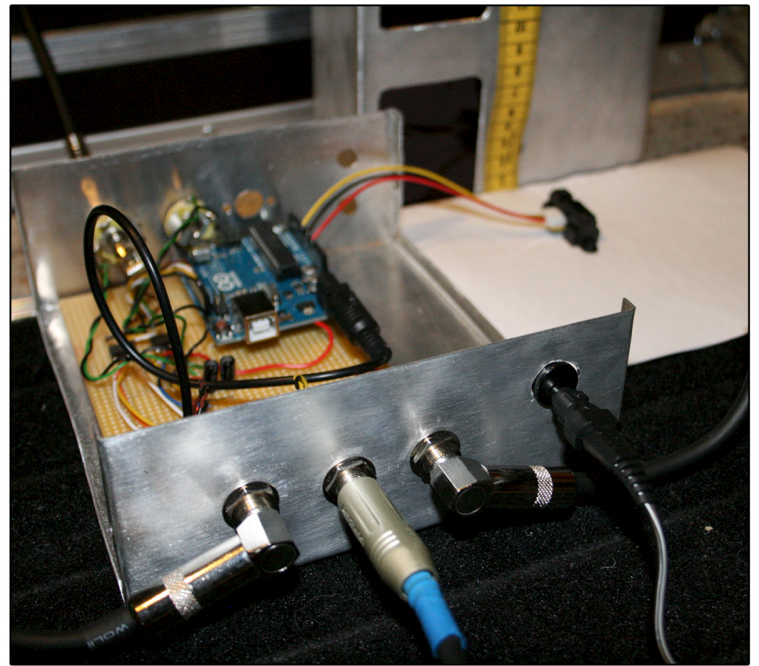
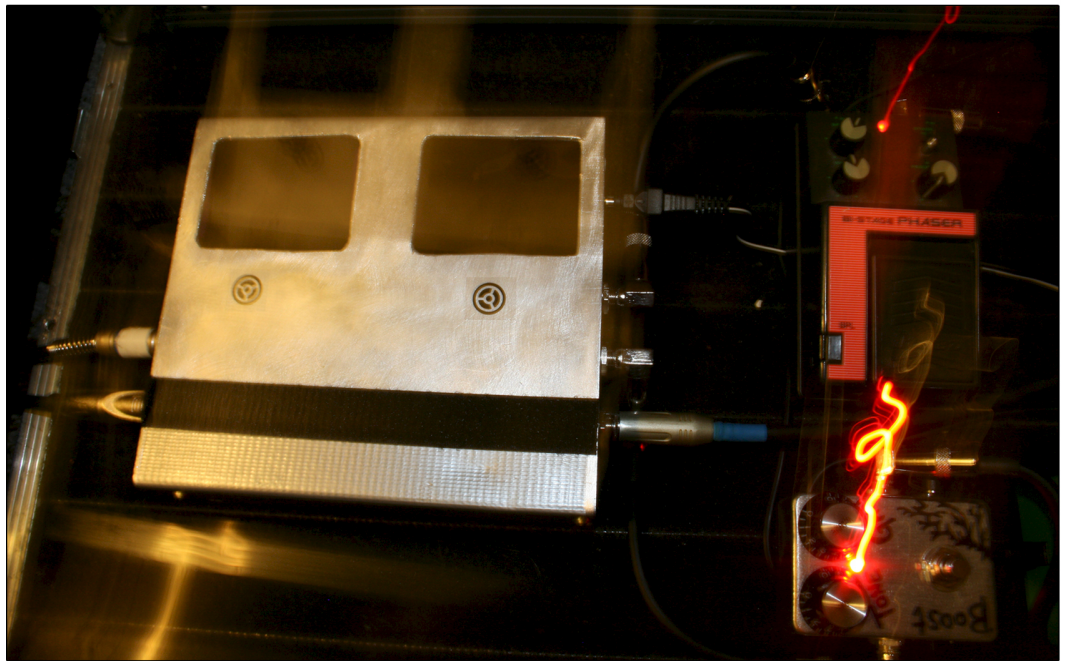
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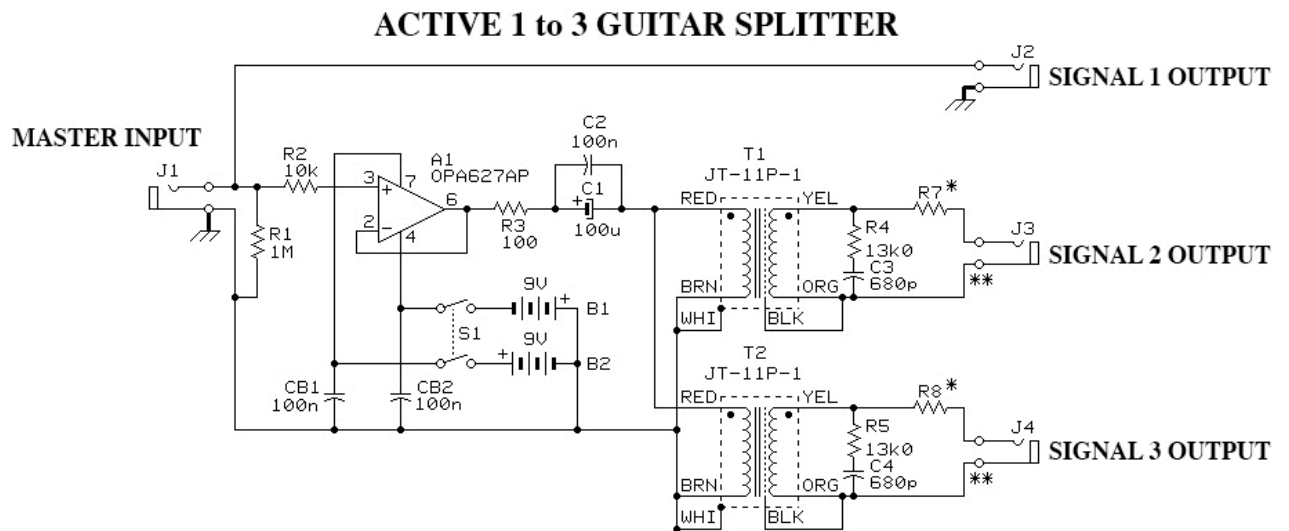






## I) APPENDIX

[Appendix 1: AirLoop-pedal (#2 and #3) Active Guitar Signal Splitter schematic diagram.]



\*R7, R8, AND R9 CAN RANGE IN VALUE UP TO 50 kΩ OR CAN BE 50 kΩ POTENTIOMETERS. THEY WILL PRODUCE TREBLE ROLL OFF SIMILAR TO THE DIRECT OUTPUT, WITH HIGHER VALUES PRODUCING THE MOST ROLL OFF.

\*\* J3, J4, AND J5 MOUNTING MUST INSULATE THEM FROM THE CHASSIS.

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[Appendix 2: Crossfader mixer of AirLoop-pedal (Prototypes #2 and #3) schematic diagram.]

### CROSSFADER MIXER of AirLoop-Pedal (Prototype #2), 2014

